1.0 INTRODUCTION

1.1 PURPOSE OF EVALUATION

The U.S. Environmental Protection Agency (U.S. EPA) intends to issue a National Pollutant Discharge Elimination System (NPDES) general permit for effluent discharges associated with seafood process wastes, process disinfectants, sanitary wastes and other waste waters to the waters of the State of Alaska and waters of the United States adjacent to State waters. Section 403(c) of the Clean Water Act (CWA) requires that NPDES permits for such ocean discharges be issued in compliance with U.S. EPA's *Ocean Discharge Criteria* for preventing unreasonable degradation of ocean waters. The purpose of this Ocean Discharge Criteria Evaluation (ODCE) report is to identify the salient information and concerns relative to the *Ocean Discharge Criteria* and discharge of seafood processing wastes in these waters.

U.S. EPA's *Ocean Discharge Criteria* (40 CFR 125, Subpart M) set forth specific determinations of unreasonable degradation that must be made prior to permit issuance. "Unreasonable degradation of the marine environment" is defined (40 CFR 125.121[e]) as follows:

"(1) Significant adverse changes in ecosystem diversity, productivity, and stability of the biological community within the area of discharge and surrounding biological communities,

(2) Threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms, or

(3) Loss of aesthetic, recreational, scientific, or economic values, which are unreasonable in relation to the benefit derived from the discharge."

This determination is to be made based on consideration of the following 10 criteria (40 CFR 125.122):

"(1) The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged;

(2) The potential transport of such pollutants by biological, physical, or chemical processes;

(3) The composition and vulnerability of the biological communities which may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the Endangered Species Act, or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain;

(4) The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism;

(5) The existence of special aquatic sites including, but not limited to, marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs;

(6) The potential impacts on human health through direct and indirect pathways;

(7) Existing or potential recreational and commercial fishing, including finfishing and shellfishing;

(8) Any applicable requirements of an approved Coastal Zone Management Plan;

(9) Such other factors relating to the effects of the discharge as may be appropriate;

(10) Marine water quality criteria developed pursuant to Section 304(a)(l)."

If the Regional Administrator determines that the discharge will not cause unreasonable degradation to the marine environment, an NPDES permit may be issued. An individual NPDES permit may be issued for distinct locations within the Alaskan coastal waters necessitating special consideration due to sensitivity or biological concern. If the Regional Administrator determines that the discharge will cause unreasonable degradation to the marine environment, an NPDES permit may not be issued.

If the Regional Administrator has insufficient information to determine, prior to permit issuance, that there will be no unreasonable degradation to the marine environment, an NPDES permit will not be issued unless the Regional Administrator, on the basis of the best available information, determines that: 1) such discharge will not cause irreparable harm to the marine environment during the period in which monitoring will take place, 2) there are no reasonable alternatives to the onsite disposal of these materials, and 3) the discharge will be in compliance with certain specified permit conditions (40 CFR 125.122). "Irreparable harm" is defined as "significant undesirable effects occurring after the date of permit issuance which will not be reversed after cessation or modification of the discharge" (40 CFR 125.121[a]).

1.2 SCOPE OF EVALUATION

The information presented here is a synthesis of data from 1993 seafood processing permit reports, current data, discharge modeling results, and findings published in the scientific literature. Where appropriate, the reader will be referred to these publications for more detailed information concerning certain topics.

1.2.1 Area of Coverage of the Proposed NPDES General Permit

This document evaluates the impacts of waste discharges as provided for by the NPDES general permit proposed for seafood processing pursuant to Section 403(c) of the Clean Water Act.

The proposed NPDES general permit authorizes the owners and operators of facilities engaged as processors of fresh, frozen, canned, and smoked seafood in offshore or inshore vessels, and shore-based vessels and onshore facilities; as well as owners and operators of offshore vessels engaged as processors of fish pastes, minces, and meals to discharge seafood process wastes, process disinfectants, sanitary wastes, and other waste waters (i.e., cooling water, boiler water, gray water, freshwater pressure relief water, refrigeration condensate, water used to transfer seafood to the facility, and live tank water) to the waters of the State of Alaska and waters of the United States adjacent to State waters in accordance with the effluent limitations, monitoring requirements, and excluded areas specified in the permit. Shore-based and nearshore facilities discharging pollock process wastes to receiving waters within one nautical mile (0.54 km) of shore at mean lower low water (MLLW) are not authorized to discharge under this general permit. wrong conversion

Several exclusions from coverage under the proposed NPDES general permit are specified. These exclusions are classified into four categories as detailed below:

*1.2.1.1 **Excluded Waterbodies***. The permit does not authorize discharges in the following waterbodies:

- Akun Island: Lost Harbor
- Akutan Island: Akutan Harbor west of 165°45'00" W
- Kodiak Island: Gibson Cove, Near Island Channel, St. Paul Harbor, Women's Bay, and Woody Island Channel.
- Unalaska Island: Unalaska Bay south of latitude 53°57'20" N, Iliuliuk Bay, Dutch Harbor, Iliuliuk Harbor, and Captain's Bay.
- Any waterbody included on Alaska Department of Conservation's (ADEC's) §305(b) report or §303(d) lists list of waters which are "impaired" or "water quality-limited" by dissolved oxygen, residues (i.e., floating solids, debris, sludge, deposits, foam, or scum), total suspended solids (TSS), or pH..

*1.2.1.2 **Protected Habitats and Areas***. The permit does not authorize discharges in the following protected habitats or special areas.

- Areas with water depth of less than 18 m (60 ft) MLLW that are likely to have poor flushing, including but not limited to sheltered waterbodies such as bays, harbors, inlets, coves, lagoons, and to semi-enclosed water basins bordered by sills of less than 30 m (98 ft) depths.

wrong conversion

- Within one nautical mile (0.54 km) of a rookery of the Steller sea lions, walrus, or northern fur seals during the period May 1 through November 30.

- Within one nautical mile (0.54 km) of a haul-out area of a group of fifty or more Steller sea lions.

- Within one nautical mile (0.54 km) of a nesting area of a colony of one thousand or more of the following seabirds during the period May 1 through September 30: puffins, auklets, eiders, murres, murrelets, petrels, and kittiwakes.

- Within one nautical mile (0.54 km) of the boundary of a State Game Sanctuary, Game Refuge, or Critical Habitat.

- Within one nautical mile (0.54 km) of a National Park, Monument, or Wildlife Refuge.

1.2.1.3 Discharges Near a Drinking Water Intake. The permit does not authorize discharges to streams or rivers within one statute mile (0.6 km) of a drinking water intake.

wrong conversion

1.2.1.4 Discharges to a Lake. The permit does not authorize discharges to lakes.

The permit does allow waivers to these exclusions if the applicant applies for a waiver and follows the requirements listed in the permit. A waiver cannot be granted until after consultation between the U.S. EPA and ADEC to determine that the discharge will comply with applicable state and federal regulations and local coastal zone management plans.

1.3 CLASSIFICATION OF DISCHARGE FACILITY

The permit includes a classification of the discharge facility as one of the following categories of seafood processors:

- *Offshore Floating Seafood Processor*: a processor operating and discharging one (1) or more nautical miles from shore at MLLW.

- *Nearshore Floating Seafood Processor*: a processor operating and discharging less than one (1) and more than one half (0.5) nautical mile from shore at MLLW.

- *Shore-based Seafood Processor*: a processor operating and discharging less than one half (0.5) nautical mile from shore at MLLW.

Specific limitations and monitoring requirements for each of these categories are set forth in the proposed NPDES general permit and will be discussed in the following sections as appropriate.

1.4 OVERVIEW OF REPORT

The evaluation focuses on sources, fate, and potential effects of seafood processing discharges on various groups of aquatic life. The types and projected quantities of discharges are detailed in Section 2.0. Anticipated amounts or volumes of wastes, proximate chemical composition, and concentrations are also given. The fate, transport, and persistence of the wastes is examined in Section 3.0, which describes the development of a seafood waste solid deposition, accumulation, and decay model and the evaluation of 12 general modeling case scenarios. These case scenarios evaluate the effects of water depth, current speed, discharge depth, and bottom slope on the model-predicted accumulation of seafood solid waste in the vicinity of stationary seafood waste discharges. This information is used to assess the potential of the deposited material to exceed the proposed NPDES permit specified zone-of-deposit (ZOD) of one acre (0.40 ha) and the probability of burying benthic infaunal invertebrates or otherwise modifying their habitat chemically or physically (e.g., via grain size changes). Before discussing potential biological and ecological effects, an overview of aquatic communities and important species is presented in Section 4.0.

correct conversion

The means by which seafood discharges could impact marine life and concentrations at which effects have been documented are presented in Section 5.0. Section 6.0 serves as the "biological assessment" of endangered and threatened species required by the Endangered Species Act (ESA). Particularly important uses and plans for the general permit area, including commercial, recreational and subsistence harvests, special aquatic sites, and coastal zone management plans, are discussed in Sections 7.0 and 8.0. Section 9.0 discusses the compliance of expected seafood discharges with federal and state water quality criteria. Section 10.0 summarizes the findings of this report and Section 11.0 presents recommendations for monitoring marine life that could be affected by seafood waste discharges in the proposed general permit area.

2.0 CHARACTER AND QUANTITY OF MATERIAL DISCHARGED

The determination of "unreasonable degradation" of the marine environment is to be based on consideration of the ten criteria listed in Section 1.0. The following section provides information pertinent for the consideration of the *ocean discharge criterion* listed below:

- **Criterion #1:** The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged.

Discharges from seafood processing facilities may be classified into solid and dissolved (or particulate and soluble) wastes. Solid wastes consist primarily of unused portions of fish and shellfish that have been processed. The unused portions of processed raw fish and shellfish include heads, skin, scales, viscera, tail fins, and shells discarded during cleaning and butchering operations. Dissolved wastes include solubilized organic matter and nutrients leached from fish and shellfish tissues during processing. The dissolved wastes may also include disinfectants used to maintain sanitary conditions in compliance with requirements for the production of food for human consumption. The solid and liquid wastes have the potential to adversely affect the marine environment. The character and quantity of Alaskan seafood processing waste is assessed below.

2.1 INTRODUCTION

Commercial seafood processing in Alaska is estimated to generate over 1.7 million metric tons (3.75 billion pounds) of solid waste each year (Figure 2-1 and Appendix A). Waste from pollock processing constitutes 59 percent of this total, with significant contributions from flatfish (other than Pacific halibut), salmon, and Pacific cod processing as well (see Figure 2-1). The estimate of solid waste produced by commercial seafood processing in Alaska also includes estimates of the at-plant discard of unprocessed target species (Table 1 of Appendix A), but the estimate does not include estimates of the discard of non-commercial species. Nonetheless, these data provide an overall assessment of the amount of solid wastes produced by the seafood industry in Alaska.

This chapter provides a summary of available data on the character and quantity of solid and liquid wastes discharged by seafood processors in Alaska. The focus of this section is on the facilities that will likely seek coverage under the new NPDES general permit. Therefore, data collection focused on annual reports for 1993 provided by Alaskan processing facilities covered under the existing general permit. Additional data that were not available in these reports were obtained from other sources including technical literature and NPDES discharge monitoring data for Alaskan seafood processors with individual permits.

Wastes are typically characterize or three distinct, but related reasons. These are the following:

- To assess the environmental impacts of the wastes discharged.
- To identify, evaluate, or design appropriate waste treatment facilities.
- To identify, evaluate, or design waste or by-product utilization techniques.

The following discussion is limited to the characteristics of the wastes that allows for an assessment of their potential environmental effects including the potential for adverse effects of seafood waste accumulation on biological communities (Section 5.0) and the potential effects of the discharge on receiving water quality (Section 9.0).

Seafood processing in Alaska is conducted in a variety of locations and under a variety of conditions. In general, processors can be separated into onshore and floating facilities. Floating facilities can further be divided into 1) shore-based facilities that are permanently or semi-permanently moored near shore, typically in relatively shallow protected areas, 2) nearshore facilities that operate temporarily or permanently in relatively protected areas to process their catch, and 3) mobile facilities that operate offshore and process their catch while in relatively deep offshore waters.

The following sections describe the 1) general fishing seasons and the locations of significant fishing areas and hence processing activity, 2) a brief overview of seafood processing techniques and the liquid and solid wastes they produce, 3) available data on Alaskan seafood processing facilities covered under the current general permit in 1993, 4) additional data available for facilities covered under individual permits in 1993, and 5) data on the characteristics of seafood waste available from the technical literature.

2.2 SEASONALITY AND LOCATIONS OF COMMERCIAL FISHING ACTIVITIES

The quantity and character of the seafood wastes generated vary considerably over the course of a year and among regions due to the distribution of exploitable fishing stocks, seasonal variation in their abundance, and the openings and closings of fishing seasons that are used to manage the target and non-target stocks of fish and shellfish species. Target species of commercial fishing operations in Alaska include groundfish (groundfish include walleye pollock, Pacific cod, sablefish, species of rockfish, Pacific halibut, and other species of flatfish), five species of salmon, herring, species of crab (Dungeness and species of king and Tanner crab), shrimp, clams, scallops, abalone, sea urchins, and sea cucumbers. The domestic and foreign groundfish fisheries, except that for Pacific halibut, in the Exclusive Economic Zone (EEZ) of the Gulf of Alaska and Bering Sea/Aleutian Islands (the EEZ extends from 3 to 200 nmi offshore) are managed by the Secretary of Commerce according to a fishery management plan prepared by the North Pacific Fishery Management Council. The Pacific halibut fishery is managed by the International Pacific Halibut Commission. Fisheries in coastal waters of the State of Alaska are managed by the Alaska Department of Fish and Game (ADF&G). For example, the ADF&G has jurisdiction over the groundfish fishery off the coast of Southeast Alaska and in the vicinity of Cook Inlet and Prince William Sound. The following sections describe the groundfish, salmon, herring, and shellfish fisheries. The term "shellfish" as used here refers to a general category that includes crabs, shrimp, scallops, clams, abalone, sea cucumber, and sea urchins.

2.2.1 Groundfish Fishery

The fishery for groundfish is generally conducted in relatively deep offshore waters in the Gulf of Alaska, Bering Sea, and offshore waters of the Aleutian Islands (Figure 2-2). The groundfish fishery off Alaska has undergone a dramatic transformation from an essentially foreign venture as late as 1981, with most processing occurring in the EEZ, to an exclusively domestic fishery by 1991, with processing occurring at shore-based facilities in Alaska as well as at sea (Kinoshita et al. 1991, Figure 2). The primary target species of this fishery are Pacific cod, walleye pollock, sablefish, and rockfish species (Kinoshita et al. 1991, Table 14).

The Alaskan groundfish fishery is closely managed by a combination of limits on target and bycatch species for specific management zones, and areas that are off-limits to fishing for the provision of safe spawning areas [e.g., Herring Savings Areas (HSAs)] or for the protection of marine mammals. The groundfish season begins on the first of January and continues throughout the year unless the fishery in a particular zone is closed because harvest or bycatch quotas have been reached.

In the Bering Sea/Aleutian Islands fishery for pollock, an "A" and a "B" season have been created. The "A" season, which targets roe pollock, begins on 20 January and is closed by 15 April. The "B" season targets non-roe pollock and begins on 15 August and continues through the end of the year or until regulatory catch limits are met (Tromble, G., 1 June 1994, personal communication). The "A" and "B" seasons are structured to control the harvest of the highly valued roe pollock during the "A" season, and to provide protection for marine mammals during the summer months (Tromble, G., 1 June 1994, personal communication). These regulatory controls on the Alaskan groundfish fishery in the Bering Sea and Aleutian Islands results in intensive fishery activity (and hence processing activity) that is concentrated during the first and last three months of the year.

A significant portion of catch harvested during the groundfish fishery consists of non-target species, prohibited species, spoilage, or target species with unsuitable characteristics that are discarded and returned to the sea unprocessed (North Pacific Management Council 1989). A conservative estimate (i.e., the actual amount may be higher) of the discarded amount of groundfish, crab, halibut, herring, and salmon resulting from the Alaska commercial groundfish fishery during 1992 was equivalent to 13 percent by weight of the total groundfish harvest of 1.89 million metric tons (4.17 billion pounds) (Pacific Associates 1993). Ninety-two percent of the estimated amount of fish discarded were groundfish. The discard of catch occurs for regulatory, economic, and operational reasons. Regulations prohibit the retention of prohibited species such as halibut, crab, and salmon and these species must be returned whole. For economic reasons spoiled target species or species that are too small may be discarded. For operational reasons target species that are too small or too large for mechanized processing equipment may also be discarded.

2.2.2 Salmon Fishery

The salmon fishery is managed by the ADF&G. Five species of salmon are managed in four distinct management regions (Figure 2-3). These management regions are 1) the Southeastern Region including Yakutat, 2) the Central Region including Prince William Sound (Copper and Bering Rivers), Cook Inlet, and Bristol Bay, 3) the Arctic-Yukon-Kuskokwim Region including Norton and Kotzebue Sound, and 4) the Westward Management Region which includes Kodiak, Chignik, and the Alaska Peninsula-Aleutian Islands (see Figure 2-3). Commercial salmon harvests have continued to establish new records since 1983 (Savikko and Simpson 1994, p. 1). A record harvest of 193 million fish was established in 1993 (Savikko and Simpson 1994, p. 1). Although the size of the commercial harvest may vary among management regions, the ADF&G is forecasting continued strong salmon runs (Savikko, H., 3 March 1994, personal communication).

The predominant commercial species are the pink and sockeye (or red) salmon which account for about 90 percent of the salmon that are harvested annually (Table 2-1). About half of the pink salmon harvest occurs in Southeast Alaska, one-quarter of the harvest is taken in Prince William Sound, and a smaller portion is taken in the area around Kodiak in the Westward Region. Well over half of the sockeye salmon harvest occurs in the Bristol Bay Area of the Central Region (see Table 2-1).

The timing of the salmon harvest is closely tied to the period when each salmon species returns to spawn. The fishing season for each salmon species depends on the management region and the type of gear used, but generally spans the period between June and September (Figure 2-4). Therefore, most of the salmon are harvested during four months of the year. In general, the relatively short salmon fishing seasons and large runs of fish result in short, but intense seafood processing activity in this sector of the industry.

2.2.3 Herring Fishery

The herring fishery is also managed by the ADF&G. Herring are harvested for food and for the bait used in the crab and longline fisheries. Sac roe is harvested immediately prior to spawning when the eggs are mature. Spawn-on-kelp fisheries are permitted in the Southeast Region, and in Prince William Sound and Bristol Bay. The food or bait harvest of herring occurs in January and February in the Southeast Region and in the Kodiak Area, and in September through November in Prince William Sound. Roe fisheries typically occur in March through June, although the fishery in any particular area may last for one month or less (Figure 2-5).

2.2.4 Shellfish Fisheries

The fisheries for crab, shrimp, scallops, clams, abalone, sea cucumber, and sea urchins are managed by the ADF&G. The largest shellfish fisheries are for crabs including red, brown, and blue king crab, opilio and bairdi Tanner crab, and Dungeness Crab. Crab fishing seasons vary depending on the region and species (Figure 2-6). Fishing seasons for Tanner (or snow) crab tend to be relatively short, and since harvest levels are relatively high compared to other target crab species [over 300 million pounds of Tanner crab were harvested in the Bering Sea during the 1991-92 season (Savikko, H., 3 March 1994, personal communication)], peak processing may occur over short periods during the year.

Shrimp fisheries are concentrated in Southeast Alaska, Cook Inlet, Pri: William Sound, and in the vicinity of Kodiak and the Alaska Peninsula. Shrimp fishing seasons occur throughout the year in various regions of Alaska depending on the type of gear used (see Figure 2-6).

The fishing seasons for clams, abalone, scallops, sea cucumber, and sea urchins depend on the type of gear used and the region (Figure 2-6). Scallop fishing generally occurs throughout the year, primarily in the vicinity of Yakutat, Kodiak, and the Alaska Peninsula.

2.3 SEAFOOD PROCESSING TECHNIQUES

Seafood processing facilities use a variety of techniques and equipment to produce marketable seafood products. Detailed descriptions of specific seafood processing facilities (e.g., salmon canning, fish meal production) are provided in U.S. EPA (1975) and Swanson et al. (1980). The material remaining after processing (e.g., heads, tail fins, guts) is typically ground and discharged as solid and liquid waste. Some solid waste material may be rendered into fish meal at a nearby meal processing facility. The processes involved in the production of marketable seafood products range from packaging whole fresh or frozen seafood for shipment, which produce relatively little solid or liquid waste, to mechanical filleting or deboning processes that produce relatively large amounts of solid and liquid waste. The remaining solid waste may be further processed into fish meal which converts much of the solid waste to marketable products.

Because seafood processing facilities use a variety of processing techniques that have a direct bearing on the quality and quantity of liquid and solid waste produced, a brief overview of the types of seafood products produced is warranted. This overview includes a description of the products produced and the recovery ranges for these products which provide an indication of the amount of solid waste produced during processing. Product types and yields were obtained from Crapo et al. (1993). These data provide average or expected recovery ranges for fish and shellfish processed under ideal conditions. A brief overview of the seafood processes that affect the quantity and quality of liquid wastes generated during processing is also provided.

2.3.1 Finfish

Whole fish may first be scaled mechanically or by hand before further processing. Selected Pacific finfish processing recovery rates are provided in Table 2-2. Finfish products include whole or dressed (i.e., gutted) fish with the head left on or removed. Yields from this type of processing range from 50 to almost 100 percent. The fish may also be processed into fillets which may be skinless and/or boneless, the yields from this type of processing range from about 25 to 50 percent. Several products specific to the type of fish species are also produced. For example, canned salmon products recover from 60 to 70 percent of the whole fish. Roe are sometimes extracted from whole herring with a yield ranging from 3 to 18 percent. Surimi production, a minced flesh product produced from walleye pollock, recovers from 11 to 22 percent of the whole fish.

2.3.2 Shellfish

Shellfish is used here as a general category that includes crabs, shrimp, scallops, clams, abalone, sea cucumber, and sea urchins. Selected Pacific shellfish processing recovery rates are provided in Table 2-3. Crab processing generally results in raw or cooked crab. The crabs may be cooked whole or in sections resulting in recoveries of about 90 and 52-60 percent, respectively, depending on the species processed. The meat may also be separated from the shell producing additional waste. The production of cooked meat results in a recovery of 17-25 percent depending on the species processed.

Shrimp processing may result in a number of products that include headed raw shrimp, whole cooked shrimp, and cooked or raw peeled shrimp. The recovery of whole cooked shrimp is about 90 percent. The product recovery rates for raw headed shrimp may range from 45 to 53 percent depending on the species processed. Recovery rates for peeled shrimp are lower and range from 30-38 percent for raw peeled shrimp to 25-26 for cooked peeled shrimp.

The recovery of marketable products from clams, abalone, and scallops is generally low (typically less than 60 percent) because the heavy shells from these animals are typically discarded. However, shell wastes from these species are not typically ground and discharged through the waste handling system of the processing facility. Shell wastes are more typically disposed of in nearby landfills or returned to the shellfish beds. Few data are available on the recovery of shellfish products from the raw meat of these organisms excluding the shell. Estimates of the recovery of cooked meats from raw meats for razor clams and scallops are 60 and 50 percent, respectively.

2.3.3 Generation of Liquid Wastes

Examples of liquid wastes generated during seafood processing include bailwater (water used in unloading and transferring fish), washdown water (including scupper and floor drain waste), scrubber water (used for removal of odors from the fish meal processing equipment), stickwater (the mixture of water, oil, proteins, fats, and ash separated from the press liquor generated during fish meal production), cooling water (generated during salmon canning), boiler water, pressure relief water, live tank water, refrigeration condensate, and sanitary wastewater.

The new general permit requires that the sanitary wastewater remain separate from the other liquid wastes generated during seafood processing. The sanitary wastewater must be treated appropriately. Appropriate methods include the use of approved marine sanitation devices, septic tank systems, or discharge to a permitted municipal wastewater treatment system.

The new general permit does not require discharge through the permitted wastehandling system and outfall of wastewaters that have not contacted seafood processing wastes. These wastewaters include cooling water, boiler water, gray water, pressure relief water, refrigeration condensate, live tank water, or bailwater. However, all waste streams that contact processing wastes (i.e., washdown water, floor drain and scupper water, scrubber water, and stickwater), must be discharged through the permitted waste handling system. The discharge of solid wastes greater than 1.3 cm (0.5 in) in any dimension is prohibited.

Washdown water and scrubber water are used to remove fish processing wastes from work areas and processing equipment. Disinfectants and detergents may be added to these waters to facilitate the removal of wastes and to maintain sanitary standards during production. The disinfectants that may be used to sanitize seafood processing areas include hypochlorite solutions (chlorine-based solutions), iodophor solutions (iodine-based solutions), and quaternary ammonium chloride solutions (chlorine- and ammonium-based solutions). The new general permit requires the monitoring of the total residual chlorine concentration of the discharged process wastewater and prohibits the discharge of wastewater containing concentrations of total residual chlorine in excess of 2.0 mg/L.

In addition to solid wastes, washdown and scrubber waters carry soluble organic wastes such as blood and other soluble fats, proteins, and carbohydrates. The amount of soluble organic wastes dissolved in the washdown and scrubber waters depends on 1) the amount of processing which damages the fish tissue and releases soluble wastes, and 2) the contact time of the water with the tissue particles. The stickwater produced during the production of fish meal consists primarily of highly soluble proteins and salts.

2.4 CHARACTERIZATION OF WASTE DISCHARGES FROM FACILITIES CURRENTLY COVERED UNDER THE GENERAL PERMIT

Historically, seafood processors have been classified as either shore-based or floating processors depending on whether the facility is land-based or is based on a floating vessel that moves up and down with the tide. However, some floating processors have characteristics that are similar to shore-based processors. A number of floating processors operate relatively close to shore and some anchor permanently or temporarily to process seafood. The new NPDES general permit provides definitions of seafood processing facilities based on the location of these facilities in relation to distance from shore. The new general permit provides the following definitions:

- *Offshore floating seafood processor*: a processor operating and discharging more than one (1) nautical mile (1.9 km) from shore at MLLW.

  correct

- *Nearshore floating seafood processor*: a processor operating and discharging from one (1) to one-half (0.5) nautical mile (1.9-0.9 km) from shore at MLLW.

  correct

- *Shore-based seafood processor*: a processor operating and discharging less than one-half (0.5) nautical mile (0.9 km) from shore at MLLW.

correct

Seafood processing operations based on floating vessels that operate within 0.9 km (0.5 nm) from shore at MLLW will be classified as a *shore-based seafood processor*. Nonetheless, the current EPA database classifies the processor as a shore-based or floating processing facility regardless of distance from shore. Because the following characterization of general permittees relied on historical data and the categories of shore-based and floating processors available in the EPA database, the terms shore-based and floating processors refer to their former definitions. The terms *shore-based seafood processor*, *nearshore floating seafood processor*, and *offshore floating processor* will be applied only when they are used as defined in the new NPDES general permit.

As of June 1994, there were 388 facilities operating in Alaska that were permitted to discharge seafood processing effluent under the National Pollutant Discharge Elimination System (NPDES) program. Of these facilities, 136 were shore-based and 252 were floating processors. An existing NPDES general permit (AKG520000) was written and intended to cover the majority of the facilities whose discharge and receiving water characteristics were similar. Approximately 82 percent of the facilities (321 out of 388) are covered under the existing general permit. A total of 84 (26 percent) of the general permittees are classified as shore-based operations and 237 (74 percent) are classified as floating processors.

To provide data on the characteristics of the Alaskan shore-based and floating processors that will likely petition the U.S. EPA for coverage under the new NPDES general permit to discharge seafood processing waste, 1993 annual reports submitted to the U.S. EPA, Region 10, by facilities covered under the existing general permit were reviewed and summarized. These data were limited by the number of reports submitted and the amount of information provided in each report. Characterization is based on a subset of 44 percent of the shore-based and 29 percent of the floating seafood processing facilities.

Facilities covered under the NPDES general permit are not normally required to monitor the composition of their process effluent. However, if sanitary wastes are not discharged to a shore-based septic system, a municipal treatment plant, or an approved marine sanitation device, secondary treatment of the sanitary effluent and monthly monitoring of 5-day biochemical oxygen demand (BOD_5) and total suspended solids is required. For process solid wastes, the only effluent limitation stipulated in the general permit is that all discharged waste particles must not exceed 1.3 cm (0.5 in) in any dimension. Additional limitations pertaining to all wastewater discharges include the prohibition of the discharge of oily waste, grease, foam, or floating solids. In addition, the accumulation of wastes on the shoreline is not allowed and no discharges may violate any Alaska State Water Quality Standards (18 AAC 70).

Monitoring requirements stipulated in the existing general permit include daily records of finished product types, pounds of raw product (including spoiled product that is subsequently discharged), and the pounds of finished product. These data can then be used to estimate the amount of solid waste discharged. For floating facilities, records of the specific location and name of the receiving water are required for the first day at each new processing location.

The data obtained from the available 1993 annual reports are summarized below for shore-based and floating processors. The summaries include monthly and annual estimates of solid waste (in wet pounds) and the general types of waste (e.g., groundfish, salmon, or crab) discharged.

2.4.1 Shore-Based Processors

As of 15 April 1994, annual reports for 1993 were available for 44 percent of the shore-based processors covered under the existing general permit. The available annual reports were from a variety of facilities throughout Alaska (Figure 2-7). In general, the available data for the shore-based facilities were considered to be a representative sample of shore-based seafood processing operations conducted under the existing NPDES general permit. Data suitable for estimating annual solid waste loading were generally available in the reports submitted by the shore-based processing facilities (84 percent). Fewer of the annual reports for the shore-based facilities contained data suitable for estimating monthly solid waste loading (65 percent). Nonetheless, the waste discharge data for shore-based seafood processing operations that are summarized below provide an indication of the monthly and annual solid waste loading from shore-based facilities that will likely seek coverage under the new NPDES general permit.

2.4.1.1 Annual Waste Discharge Amounts. The annual waste discharges from the shore-based facilities for which data were suitable for estimation ranged from a minimum of 0.018 to 64.0 million pounds. The frequency distribution of the annual discharge of seafood waste from these facilities is positively skewed with over 85 percent of the facilities discharging less than 12 million pounds of seafood waste in 1993 (Figure 2-8). The median annual waste discharge from these facilities in 1993 was 2.37 million pounds. The 27 shore-based facilities that discharged less than 12 million pounds of solid waste in 1993 are shown in Figure 2-9. Of these 27 facilities, 81 percent discharged less than 4 million pounds of solid waste in 1993.

Figure 2-10 shows the annual distribution of seafood solid waste discharge by general fish type including salmon, pollock, and cod. These data indicate that 50 percent of the solid waste discharged by shore-based seafood processing facilities is derived from salmon processing. Pollock processing accounted for an additional 24 percent of the annual solid waste discharge in 1993 from shore-based processors. The relatively large contribution of pollock waste was due primarily to processing waste from one of the 31 facilities for which data were available.

2.4.1.2 Seasonal Variability. Fewer reports provided data suitable for calculation of monthly seafood solid waste discharge. Sixty-five percent of the reports provided information on monthly solid waste discharge. These data provide an indication of the typical seasonal distribution of solid waste discharged from shore-based seafood processing operations. The available data indicate one pronounced peak in solid waste discharge (Figure 2-11). This peak occurs in June, July, and August.

Figure 2-12 shows the monthly distribution of seafood solid waste discharge by general fish type including salmon, pollock, and cod. These data indicate that the predominant seasonal peak in seafood processing waste is due to waste from salmon processing and a lesser amount of pollock in June, July, and August (see Figure 2-12). Peaks in February and March are due primarily to the processing of cod and the peak in April is due to salmon processing. The relatively large amount of solid waste discharge in September is due to pollock processing and a lesser amount of salmon (see Figure 2-12). As for the 1993 annual estimate of seafood waste discharge product type, one facility accounts for the relatively large seasonal discharge of pollock processing waste.

2.4.2 Floating Processors

As of 15 April 1994, annual reports for 1993 were available for 29 percent of the floating processors covered under the existing general permit. The available annual reports were from a variety of floating facilities located throughout Alaska (Figure 2-13). Estimates of annual solid waste discharge were possible from 41 percent of the available reports. Although fewer annual reports for floating facilities were available for review, the annual waste discharge amounts and types of species processed annually are considered to be representative of the floating processors that will likely seek coverage under the new general permit. However, the available monthly data for the floating processors were not considered to be as representative of floating seafood processing operations conducted under the existing NPDES general permit. This was due to the fewer number of available annual reports that were suitable for estimating monthly solid waste discharge. Monthly estimates of waste discharge were possible for 32 percent of the available reports. The monthly distribution of solid waste discharge by species type was also not considered to be representative because the floating facilities that reported the greatest annual discharge did not report the type of species processed each month. The floating facilities processing the largest amount of waste annually are processing pollock. Keeping the above qualifications in mind, the available data for the floating processors covered under the existing general permit are summarized below.

2.4.2.1 Annual Waste Discharge Amounts. The annual waste discharges from the floating facilities for which data were suitable for estimation ranged from a minimum of 0.0075 to 79.0 million pounds. The frequency distribution of the annual discharge of seafood waste from these facilities is positively skewed with 75 percent of the facilities discharging less than 12 million pounds of seafood waste in 1993 (Figure 2-14). The median annual waste discharge from these facilities in 1993 was 1.51 million pounds. The 21 floating facilities that discharged less than 12 million pounds of solid waste in 1993 are shown in Figure 2-15. Of these facilities, 86 percent discharged less than 4 million pounds of solid waste in 1993.

Figure 2-16 shows the annual distribution of seafood solid waste discharge by general fish type including salmon, pollock, and cod. These data indicate that 58 percent of the solid waste discharged by floating seafood processing facilities is derived from the processing of pollock. Unspecified species of groundfish, cod, and unspecified species of fish accounted for 26 percent of the fish processed annually and crab, salmon, and meal processing contributed 15 percent of the solid waste.

2.4.2.2 Seasonal Variability. Fewer reports provided data suitable for calculation of monthly seafood solid waste discharge. Thirty-two percent of the reports provided information on monthly solid waste discharge. These data may not be representative of the typical seasonal distribution of solid waste discharged from floating seafood processing operations because of the limited number of monthly discharge data available and because the largest facilities do not typically report data suitable for calculating monthly waste discharge. However, the available data indicate two peaks in solid waste discharge (Figure 2-17). The first peak occurs in February and the second peak occurs in September (see Figure 2-17).

Figure 2-18 shows the monthly distribution of seafood solid waste discharge by general fish type including salmon, pollock, and cod. These data indicate that the first seasonal peak in seafood processing waste is due primarily to waste from crab, groundfish, and unspecified fish processing in January, February, and March. The second peak in processing consists primarily of salmon and groundfish processing in June and July; unspecified fish, salmon, pollock, and meal processing in August; and unspecified fish, pollock, and meal processing in September. Note that because monthly solid waste discharge data from floating processors producing pollock are lacking, these data do not present an accurate assessment of the overall monthly discharge from floating processors.

2.5 CHARACTERIZATION OF WASTE DISCHARGES FROM FACILITIES CURRENTLY COVERED UNDER INDIVIDUAL PERMITS

Of the 388 seafood processing operations in Alaska as of June 1994, 53 facilities have been issued individual NPDES permits because they are located in one of several areas excluded from the general permit (e.g., Akutan, Kodiak, Unalaska/Dutch Harbor), discharge to shallow waters [< 13 m (42 ft)] with poor flushing, or are located within one-half mile of areas of special concern. Fifty-one of the 53 individual permits have been issued to shore-based facilities. As in the previous section (see Section 2.4) the use of the terms "shore-based" and "floating" facilities follows that of the existing NPDES general permit.

Although this document is intended to aid in the development of the new NPDES general permit for seafood processing facilities, effluent quality monitoring data are only available for individual NPDES permittees. Permit requirements identical to those described for facilities covered under the existing general permit are also stipulated in all individual NPDES permits, but facilities covered under individual permits are also required to monitor their process effluent for variables such as pH, TSS, BOD_5, and oil/grease. Individual permittees are required to submit monthly Discharge Monitoring Reports (DMRs) to U.S. EPA, Region 10, summarizing the monitoring performed in the previous month. The data from these DMRs are entered into U.S. EPA's Permit Compliance System (PCS) database. As part of this report, all available DMR data from 1992-93 for Alaskan individual seafood permittees were summarized. It should be noted that the quality of effluent discharged by facilities covered under the general permit may be different than that of the facilities covered under individual permits. Table 2-4 includes data for TSS, oil/grease, and BOD_5 for the 31 shore-based processors for which effluent quality data have been entered to PCS. They are generally the largest seafood processing facilities in Alaska (i.e., classified as major facilities), although six minor facilities are also included in this summary. Data for these parameters are not normally reported by floating processors, although those facilities covered under individual NPDES permits are required to do so.

Caution should be used when comparing the median and maximum values for each effluent type because the data points, even if equal in number, may be from different facilities or time periods. These data are meant to provide a summary of the measured ranges for selected effluent variables. The data provided include both effluent concentration and mass loading estimates for various types of wastestreams. Because mass loading is a function of both concentration and flow, differences in concentrations of the measured effluent variables in different wastestreams may not be reflected in the estimated loadings for these same wastestreams.

Section 2.5.1 describes the concentrations of TSS, oil/grease, and BOD_5 measured in various types of seafood processing effluent. Section 2.5.2 summarizes the volume of wastewater discharged, the mass loading of BOD_5, TSS, and oil/grease to the receiving water bodies, and production data (in pounds of raw and finished product) for 1992-93.

2.5.1 Effluent Monitoring Data

The data summarized in Table 2-4 have been grouped according to a descriptor field included in PCS which describes the species (i.e., product) or monitoring location associated with the reported effluent data. The definition of each of these classifications is given in Table 2-4. The data were grouped in this manner because it was anticipated that the characteristics of each wastestream would differ depending on the species being processed (e.g., salmon vs. crab) or the type of wastestream sampled (final effluent vs. stickwater). For each wastestream classification, the median value, number of samples (n), minimum value, and maximum value are given for TSS, oil/grease, and BOD_5. The median value was reported rather than the mean value because the mean would tend to misrepresent the central tendency of the data given the large skew of the reported values. For the same reason, no variance statistics (e.g., standard deviation) were calculated.

For each of the three parameters, the median of the reported monthly average (mean of all measurements for the month) and the median of the daily maximum (maximum of all measurements for the month) are reported in mg/L (see Table 2-4). It should be noted that it is possible for the median monthly average to be higher than the median daily maximum (e.g., BOD_5 for surimi) if the data points are not matched pairs. The median monthly average and median daily maximum for TSS ranged from 36 mg/L and 43 mg/L, respectively, for crab to 176 mg/L and 215 mg/L, respectively, for salmon. The total waste-stream classification, which typically represented the final effluent from mixed waste sources, was near the higher end of the range, with a median monthly average of 150 mg/L and a median daily maximum of 202 mg/L. TSS concentrations for surimi operations were approximately an order of magnitude higher than for the other product groups (median monthly average = 1,079 mg/L and median daily maximum = 1,366 mg/L), reflecting the fact that wastewater from this type of production results in the discharge of more solids. Similarly, the TSS values for stickwater discharge from meal plants are also high (median monthly average = 4,900 mg/L and median daily maximum = 9,540 mg/L). TSS values for the meal category are within the range noted for the individual product classes above (median monthly average = 88 mg/L and median daily maximum = 142 mg/L).

The median monthly average and median daily maximum for oil/grease ranged from 13 mg/L and 18 mg/L, respectively, for crab to 141 mg/L and 166 mg/L, respectively, for the total group. Oil/grease concentrations for surimi operations were slightly higher than for the other product groups (median monthly average = 208 mg/L and median daily maximum = 257 mg/L). Conversely, the oil/grease values for stickwater discharge from meal plants was lower than all other product groups (median monthly average = 2.1 mg/L and median daily maximum = 5.6 mg/L). Oil/grease values for the meal category were within the range noted for the individual product classes above (median monthly average = 28 mg/L and median daily maximum = 44 mg/L) as were the oil/grease values for the salmon category (median monthly average = 90 mg/L and median daily maximum = 116 mg/L).

BOD_5 is not typically measured for individual product groups (e.g., salmon, crab, or herring), but it is measured for the total category and in wastestreams associated with surimi and meal production. BOD_5

values are similar to those reported for TSS, although fewer values were reported. The total wastestream category values were 155 mg/L (median monthly average) and 164 mg/L (median daily maximum) for BOD_5. BOD_5 values were much higher for surimi (median monthly average = 2,323 mg/L and median daily maximum = 1,845 mg/L) and stickwater (median monthly average and maximum = 7,600 mg/L). BOD_5 values for the meal category were less than those for the total wastestream category (median monthly average = 80 mg/L and median daily maximum = 120 mg/L).

In addition to the effluent quality data reported above, a limited amount of nutrient data (i.e., nitrogen and phosphorus) has been collected for Alaskan seafood processing facilities. In a recent study completed in Akutan Harbor, final effluent, surimi effluent, and stickwater effluent were monitored for final phosphorus (TP), ammonium nitrogen (NH_4-N), nitrate+nitrite nitrogen (NO_2+NO_3-N), total Kjeldahl nitrogen (TKN), and total organic carbon (TOC) (Tetra Tech 1993). Concentrations (mg/L) were similar between the final effluent and surimi effluent (TP ~ 50, NH_4-N ~ 5-20, NO_2+NO_3-N ~ 0.16, TKN ~ 400, and TOC ~ 2,500 mg/L). The nutrient concentrations in stickwater, however, were 10 to 30 times higher for all nutrients than for the final effluent and surimi effluent. The nutrient concentrations of final effluent and surimi effluent closely correspond to each other, in spite of the high stickwater nutrient concentrations because the stickwater contributes a relatively small portion of the total mass loading of these substances.

2.5.2 Quantity of Materials Discharged

The quantity of seafood processing effluent discharged, like the composition of the effluent, will vary significantly between facilities and will depend on the time of year and the species being processed. Table 2-5 presents both flow and production data for Alaskan shore-based seafood processors for 1992-93. Discharge (flow) data are presented in Table 2-5 for the crab, salmon, total, meal, stickwater, and surimi wastestream categories. The median monthly average ranged from 0.006 m^3/sec (0.14 MGD) for salmon to 0.074 m^3/sec (1.7 MGD) for surimi. The total wastestream category contained the largest body of data (n=416) for flow. The median monthly average and median daily maximum flow were 0.009 and 0.03 m^3/sec, respectively (0.20 and 0.69 MGD).

The flow data from a seafood processing facility do not provide a complete picture of potential effects on receiving water quality. Many of the facilities in the PCS database also report loading data for TSS, oil/grease, and BOD_5. These data are presented in Tables 2-6, 2-7, and 2-8. These data are presented in three different units: pounds/1,000 pounds of production (lb/1,000 lb), lb/month, and lb/day. Generally only one or two of the units are reported for a particular product group. For TSS in the lb/1,000 lb production units, the median monthly average ranged from 1.1 for stickwater to 5.2 for the total category (see Table 2-6). TSS loading data in the lb/day units were only reported for the total, meal, stickwater, and surimi groups. The median monthly average for stickwater and surimi (14,715 and 11,831 lb/day, respectively) was approximately two orders of magnitude higher than for the meal and total effluent groups (48 and 164 lb/day, respectively). TSS loading in lb/month was only reported for the total effluent group. The median daily maximum (monthly average data were not reported) was 492,542 lb/month.

Oil/grease loading data are presented in Table 2-7. In the lb/1,000 lb units, oil/grease loading ranged from a median monthly average of 0.04 for stickwater to 2.2 for the salmon group. The median monthly average loading for the total effluent group was 1.6 lb/1,000 lb production. Oil/grease loading data in the lb/day units were only reported for the total effluent, meal, stickwater, and surimi groups. The median monthly average for surimi (1,337 lb/day) was almost two orders of magnitude higher than for the meal and total effluent groups (16 and 944 lb/day, respectively). Oil/grease loading for stickwater was low (median monthly average = 2 lb/day), in spite of the high concentration in the effluent, although the median monthly average in loading units was based on only 4 data points and the median monthly average in concentration units was based on 53 data points. Oil/grease loading in lb/month was only reported for the total effluent group. The median daily maximum (median monthly average was not reported) was 29,163 lb/month.

BOD_5 loading data (Table 2-8) were only reported for the total effluent, meal, stickwater, and surimi groups, although each of the other individual groups was included in the table for consistency. BOD_5 loading per unit of production ranged from 0.30 lb/1,000 lb production for stickwater to 1.4 lb/1,000 lb production for the total effluent group. BOD_5 loading data in the lb/day units were only reported for the total, meal, stickwater, and surimi groups. The median monthly average for stickwater and surimi (39,100 and 11,190 lb/day, respectively) was approximately two orders of magnitude higher than for the meal group (112 lb/day). The BOD_5 loading for the total effluent group was higher still (108,988 lb/day). BOD_5 loading in lb/month was only reported for the total effluent group. The median daily maximum (median monthly average was not reported) was 910,350 lb/month.

2.6 BOTTOM ACCUMULATIONS OF SOLID WASTE

Although not strictly a characteristic of the waste itself, the accumulations of waste solids on the bottom in the vicinity of seafood waste discharges is a characteristic of a number of Alaskan seafood processing facilities covered under the existing NPDES general permit. The available information regarding the characteristics of these waste accumulations (also known as wastepiles) is summarized below.

Dive surveys or bottom sampling are required of seafood processing permittees to determine the presence or absence of accumulations of wastes on the sea bottom in the vicinity of the process waste discharge. The permittees may conduct either dive surveys or bottom sampling (prior to consultation with U.S. EPA) to determine the presence/absence of solid waste accumulation on the bottom in the vicinity of the processing discharge. If waste accumulation on the bottom is observed, the dive survey should document the extent of the accumulation, the dispersion of the waste, and any impacts on the benthic community and water column.

Because the existing general permit requires two bottom sampling surveys (one in each of the first two years of operation while covered under the permit), dive surveys or bottom sampling were reported in only 30 percent of the 1993 annual reports that were available. All of these reports were submitted by shore-based facilities. Two of the surveys reported using a grab sampler which did not indicate the presence of seafood waste on the bottom in the vicinity of the discharge. Of the nine remaining surveys that were conducted by divers, seven indicated the presence of waste solids accumulation on the bottom. The extent of the waste accumulation observed at each facility ranged from an area of approximately 2 m^2 (21 ft^2) and maximum depth of 15 cm (6 in) to a pile with a maximum depth of approximately 2 m (7 ft) and an area of approximately 2,900 m^2 (31,400 ft^2). All seven solid waste piles reported were less than 4,047 m^2 (43,560 ft^2) or one acre in area.

Compliance inspections conducted by the U.S. EPA in 1991 at shore-based facilities in Cordova, Ketchikan, Sitka, and Valdez, Alaska, also indicated the presence of solid waste accumulations in the vicinity of seafood waste discharges covered under the existing NPDES general permit, although the areal extent of these accumulations were not determined. The inspections did reveal that at that time, several of these facilities were not in compliance with the NPDES general permit requirement for the grinding of solid waste to less than 0.5 in (1.3 cm) prior to discharge. Divers observed active seafood waste discharges that contained whole fish heads, gill rakers, fins, and internal organs that had not been ground to the required dimensions before discharge. The discharge of larger waste particles may have been a contributing factor to the accumulation of waste in the vicinity of these seafood processing operations.

Additional factors that affect the areal coverage and depth of seafood solid waste accumulations (e.g., current speed, waste particle settling velocities, and waste decay rate) are discussed in Section 3.0 which describes the development of a mathematical model to predict the areal extent of bottom accumulations of seafood solid waste.

2.7 EFFLUENT TOTAL RESIDUAL CHLORINE CONCENTRATION

Additional monitoring requirements for shore-based and near-shore floating facilities include weekly monitoring of effluent total residual chlorine concentrations. Effluent monitoring for residual chlorine is to be conducted coincident with the use of chlorinated disinfectants or cleansers during equipment scrubbing and washdown.

Because the existing NPDES general permit requires residual chlorine monitoring in only the first year of operation under the existing general permit, only 19 percent of the facilities for which the 1993 annual reports were available reported chlorine monitoring results. The data submitted did not always include the reporting units or the laboratory detection limits when residual chlorine was not detected. The reported values included zero (three facilities), less than 1 mg/L (one facility), "trace" (one facility), and 3 mg/L (one facility).

Effluent total residual chlorine monitoring data were also available for individual permittees from PCS. For the period 1992-93 approximately 600 effluent total residual chlorine concentrations were reported by individual permittees. Of these values only 47 (8 percent) values were greater than zero. Forty-two values that were greater than zero ranged from 0.5 to 3.0 mg/L and were reported by one facility. The five remaining values were all less than or equal to 2.0 mg/L. As for the data from general permittees, the data submitted did not include the laboratory detection limits when residual chlorine was not detected (i.e., reported as zero).

Although the available data indicate that effluent total residual chlorine concentrations are generally below 2.0 mg/L, additional information is necessary to fully evaluate these results. The additional information required includes laboratory detection limits, the analytical method used, and a description of the sampling protocol used to ensure that representative samples were collected of the wastewater produced from the disinfection of seafood processing areas. These data were not available in the annual reports from the NPDES general permittees or from the PCS database for individual permittees.

2.8 PROXIMATE AND CHEMICAL COMPOSITION OF SEAFOOD SOLID WASTE

Additional characteristics of seafood waste that are relevant to the assessment of potential adverse impacts include the proximate and chemical composition of the solid waste. In general, seafood processing solid waste consists of both organic and inorganic material. Table 2-9 presents the results of several studies in which various types of fishery waste were measured for the percentages of protein, fat, ash, and moisture. Most of the solid fish waste was at least 75 percent water. The percentages of protein were similar for most types of fish waste (approximately 10-15 percent wet weight), although skinner wastes were higher (18-20 percent wet weight). The percentage of fat was generally less than 3 percent, although heads of halibut and salmon, and viscera from pollock had a much higher fat content (16-17 percent and 40 percent of wet weight, respectively). The percentage of ash, which represents the inorganic component of fish waste, was generally less than 5 percent wet weight, although crab waste, with its large fraction of connective tissue (chitin), had ash percentages closer to 10 percent wet weight.

Based on the proximate analysis data provided above, a general chemical composition and density of seafood waste may be formulated. This general formulation is presented in Table 2-9. The actual values for specific seafood waste discharges will depend primarily on the type of species processed (e.g., fish vs. shellfish) and the types of finished products (e.g., headed and gutted vs. gutted only). Consequently, processing wastes that contain wastes with a higher proportion of bone or shell waste will likely have a higher content of inorganic material (i.e., ash). A waste with a higher content of skeletal material will also generally be more dense.

The carbon, nitrogen, phosphorus, and sulfur content of the solid waste can also be estimated assuming a carbon content of 50 percent of the dry weight mass and the Redfield ratio of carbon, nitrogen, and phosphorus (see Table 2-10). The estimates of nitrogen, phosphorus, and sulfur compare favorably to other values based on calculated or measured concentrations in whole and waste portions of fish and shellfish (see Table 2-11). The actual concentrations of nitrogen, phosphorus, and sulfur in seafood solid waste will depend primarily on the protein and solubles content of the waste which contains nitrogen, phosphorus, and sulfur, and the amount of chitin which also contains nitrogen.

2.9 SUMMARY

The timing and location of commercial fishing activity determines the timing and location of seafood processing activity. Because of relatively intense fishing pressure and because some fisheries rely on spawning activity to concentrate fish for harvest, commercial seafood processing activity occurs during a relative short, but intense periods over the course of the year depending on the species processed. For example, pollock processing activity in the Bering Sea and Aleutian Islands is concentrated in the first and last three months of the year. Salmon processing coincides with the peak salmon runs during June through September.

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The characteristics of seafood processing effluent are dependent on several factors, including the time of year, the species being processed, the type of product, and the production machinery utilized at the facility. Limited data were available to characterize the seafood waste discharged by the individual shore-based and floating facilities currently covered under the NPDES general permit. Nonetheless, it appears that individual facilities discharged from 0.0075 to 79.0 million pounds of solid waste in 1993. The median quantity of solid seafood waste discharged by 31 shore-based seafood processors was 2.37 million pounds. The median quantity of solid seafood waste discharged by 28 floating processors was 1.51 million pounds. Most of the shore-based and floating facilities evaluated discharged less than 12 million pounds of waste in 1993. Shore-based facilities covered under the existing general permit process several species over the course of the year, but salmon processing appears to be a predominant activity in June through August. A more limited number of these shore-based facilities process relatively large amounts of pollock. Floating seafood processing facilities covered under the existing general permit also process a variety of species over the course of the year, but pollock and other groundfish processing predominates. Because the monthly discharge data for floating processors were limited, the monthly discharge patterns of floating processors could not be adequately characterized.

Of the shore-based facilities for which data were summarized, seven provided information regarding the presence and extent of solid seafood waste accumulations on the sea bottom in the vicinity of the discharge. These waste piles ranged from approximately 2 m^2 (21 ft^2) and a maximum depth of 15 cm (6 in) to 2,900 m^2 (31,400 ft^2) and a maximum depth of 2 m (7 ft). None of these seven waste piles covered a bottom area greater than 4,047 m^2 (43,560 ft^2) or one acre in area.

Additional data available for shore-based seafood processors currently covered under individual permits were also summarized. The concentrations of TSS, oil/grease, and BOD_5 reported by shore-based, individual NPDES permittees varied over a wide range within a particular product category. The concentration of TSS, oil/grease, and BOD_5 and wastewater flow rate were generally highest in the stickwater and surimi wastestreams, with the exception of oil/grease in the stickwater wastestream which was typically lower than the concentrations measured in other process wastestreams. Effluent loading data in units of pounds per day were available for the total (i.e. combined or final effluent), meal, stickwater, and surimi wastestreams. Effluent loading of TSS was highest for the stickwater category (median monthly average = 14,715 lb/day). Effluent loading of oil/grease was highest for the surimi category (median monthly average = 1,337 lb/day). Effluent loading of BOD_5 was greatest for the total effluent category (median monthly average = 108,988 lb/day).

Effluent total residual chlorine monitoring data reported by NPDES general permittees and individual permittees indicated that effluent residual chlorine concentrations are typically less than 2.0 mg/L. However, residual chlorine data reported as zero did not include the laboratory detection limit of the analysis. Additional information necessary to fully evaluate the residual chlorine data include the analytical methods used and the sampling protocol followed to ensure that effluent samples representative of process area disinfection are collected.

Additional data were also identified regarding the chemical and proximate composition of seafood waste. In general these data were relatively limited. The proximate composition (percentage of protein, fat, and ash) of seafood solid waste, which influences the rate at which the deposited material is degraded, is relatively consistent for most fish waste, but differs considerably for crab waste (crab waste contains more ash) and for discharges of fish heads and viscera only (more fat and ash). A typical solid seafood waste composed of 75 percent moisture, 7 percent protein, 15 percent fats and carbohydrates, and 4 percent bone or chitin and connective tissue is predicted to contain approximately 50, 8.8, 0.8, and 0.8 percent dry weight of carbon, nitrogen, phosphorus, and sulfur, respectively, based on theoretical stoichiometric relationships for these waste components. In general, these estimates agree well with the limited data available on the measured chemical composition of whole fish and seafood waste reported in the literature.

3.0 TRANSPORT, FATE, AND PERSISTENCE OF MATERIALS DISCHARGED

Alaskan seafood processing results in the discharge of wastewater consisting of solid and liquid wastes. These wastes consist primarily of dissolved and particulate organic matter and nutrients. Depending on the type and amount of waste discharged, and the physical, biological, and chemical characteristics of the receiving water, wastewater discharges from seafood processors have the potential to impair designated beneficial uses of the marine waters of Alaska. These potential adverse effects on the quality of marine waters of Alaska include reduction in water column dissolved oxygen due to the decay of particulate and soluble waste organic matter, the release of toxic levels of sulfide and ammonia from decaying waste, nutrient enrichment (eutrophication) and stimulation of phytoplankton growth and alteration of the phytoplankton community, and the accumulation of buoyant waste solids and fish oils on the water surface and shorelines.

Seafood waste discharges also have the potential to accumulate on the receiving water bottom in the vicinity of the discharge. The accumulation and decay of seafood waste solids results in the smothering of benthic marine organisms, and the release of carbon dioxide, methane, ammonia, soluble phosphorus, and hydrogen sulfide. The decay of the waste accumulation and the release of microbial decomposition by-products (e.g., sulfide and methane) also exerts a demand on the dissolved oxygen content of the overlying water column and within the sediments. These potential impacts on marine organisms are discussed in detail in Section 5.0 and the potential for exceedances of Alaska's marine water quality criteria are discussed in Section 9.0.

The following section describes a conceptual model of the transport, fate, and persistence of discharges from seafood processing facilities in Alaska and the potential adverse environmental impacts due to these discharges. The development of a computer model to predict the accumulation, persistence, and areal coverage of discharged seafood solid wastes is also described and the results of model case studies are summarized.

Because a number of Alaskan seafood waste discharges have resulted in the persistence of bottom accumulations of waste (see Section 2.6), and adverse effects on benthic organisms have been observed in the vicinity of the discharge (see Section 5.2), the focus of this section is primarily on the transport, fate, and persistence of seafood waste solids. Because the new NPDES general permit includes the allowance of a persistent (i.e., year-round) bottom accumulation of seafood waste of no more than 0.40 ha (1.0 ac), predicting the bottom area covered by seafood solid waste accumulations and the depth of the deposited solids on the bottom as a function of distance from the discharge point is also of interest.

This section begins with the description of a generalized conceptual model of the significant variables (biological, chemical, and physical) that affect the transport, fate, and persistence of seafood waste discharges (Section 3.1), followed by a description of the development of a computer model to predict the deposition of seafood solid waste and the selection of model input variables and modeling case scenarios (Section 3.2). A summary of the results of twelve modeling case scenarios based on the selected input variables to the computer model is also provided (Section 3.3).

3.1 CONCEPTUAL MODEL OF SEAFOOD WASTE DISCHARGES

The following is a description of a conceptual model of the most important factors that control the fate, transport, and persistence of seafood processing waste discharges, including the potential adverse environmental impacts associated with the discharge of seafood waste. The conceptual model is presented graphically in Figure 3-1.

Seafood wastewater discharges consist of a combination of dissolved and solid waste particles (see Section 2.0). The dissolved portion of the waste consists of water soluble organic compounds and soluble nutrients. The liquid portion of the waste may also contain disinfectants used to clean the processing areas. The solid fraction of the waste should be ground to a particle size of 1.3 cm (0.5 in) diameter or less before discharge. The solid fraction consists of a variety of particles which may range from small bits of bone, shell, fat, or flesh to larger fragments of internal organs and fragments of flesh and fat attached to bone, shell, or connective tissue. Thus the solid fraction likely consists of a range of solid particle sizes with chemical compositions and densities that depend on the relative amount of protein, fat, bone, chitin, and connective tissue in each particle.

Once discharged to the receiving water, the rate at which the liquid and solid wastes are dispersed and advected away from the point of discharge will depend on the physical and chemical properties of the discharged waste discussed above, and the physical oceanographic characteristics of the receiving water. These oceanographic characteristics include the location of the discharge in the water column, the presence or absence of density stratification, water depth and bottom topography, and prevailing directions and speeds of wind- and tidally-forced currents. The solid waste particles will settle to the bottom at a rate that depends on the shape, density, and size of the individual particles. Once deposited on the bottom, periods of high currents or storm wave-induced bottom turbulence can result in the resuspension and transport of deposited seafood waste solids away from the point of discharge.

Following their discharge to the receiving water, the particulate and soluble wastes are subjected to chemical and biological transformations that result in the decomposition of the waste materials and the production of bacteria and chemical compounds. The decomposition of the soluble and particulate organic matter consumes dissolved oxygen and results in the production of varying quantities of soluble compounds including carbon dioxide, methane, ammonia, soluble phosphorus, and hydrogen sulfide. Scavenging organisms including fish, crabs, and polychaete worms may also feed on the particulate waste that is suspended in the water column or fresh waste that has accumulated on the bottom.

The adverse environmental effects associated with the discharge include reduction of water column dissolved oxygen concentrations and reduction of oxygen in sediments affected by decaying waste accumulated on the bottom. Seafood wastes also have the potential to be toxic to marine organisms via the discharge of wastewater containing ammonia and residual chlorine compounds and the bacterially-mediated production of ammonia and hydrogen sulfide from decaying waste accumulations. Direct smothering of benthic organisms may occur due to the accumulation of seafood waste on the bottom. If phytoplankton in the vicinity of the waste discharge are nitrogen or phosphorus limited, the additional nutrients supplied by the waste discharge may increase phytoplankton productivity and alter the species composition of the phytoplankton community.

The available information on the character and quantity of Alaskan seafood processing waste discharges has been summarized in Section 2.0. The most important variables that affect the transport, fate, and persistence of seafood processing wastes subsequent to their discharge to receiving waters are 1) the physical oceanographic characteristics of the receiving water, 2) the distribution and settling velocities of the waste particles, and 3) the loss processes and decay rates of the discharged organic matter. The available information on these variables that is relevant to predicting the transport, fate, and persistence of seafood processing waste discharges to marine waters of Alaska is summarized below.

3.1.1 Physical Oceanographic Characteristics of the Receiving Water

Significant physical oceanographic characteristics to consider include water temperature, density stratification, and water circulation in the vicinity of seafood processing discharges. Significant seasonal variation in water temperature and density structure occur in the Gulf of Alaska and the Bering Sea, especially in coastal waters in the vicinity of large freshwater inputs during winter and spring. Elevated surface water temperatures lower the saturation concentration of dissolved oxygen. Warmer surface waters overlying colder water also results in greater density stratification. Warmer surface waters occur in late summer. Density stratification of the water column can result in the trapping of waste discharges well below the water surface which may result in lowered dilution of the wastewater discharge, but prevent the appearance of the wastewater plume on the water surface.

Water circulation results in the advection or transport of discharged wastewater, and when bottom currents (or wind-induced waves) are strong enough, solid wastes that have settled on the bottom may be resuspended and transported away from the discharge. Water circulation occurs through wind- and tidally-driven currents. The amount of wind- and tidally-induced circulation will vary seasonally, and tidally-induced currents will vary over the course of the day in many coastal areas of Alaska which experience semidiurnal tides. Wind-driven circulation most strongly influences circulation patterns during winter storms that frequent the Gulf of Alaska and Bering Sea.

Although it would be difficult to classify the marine waters of Alaska into regionally distinct oceanographic regimes, some generalizations can be made from the available data on tide ranges and maximum tidal currents (Table 3-1). Tide ranges and hence tidal currents are generally highest in the areas of Southeast Alaska, Prince William Sound, Cook Inlet, and Bristol Bay. Diurnal tides range between 3.1 and 8.8 m (10.1-28.8 ft) at Yakutat and Anchorage, respectively. Maximum tidal current speeds in these areas range from 0.05 to 1.8 m/sec (0.1-3.5 kn) at Juneau and Anchorage, respectively. The highest tide ranges and tidal currents occur in Cook Inlet, an estuary with one of the greatest tidal amplitudes and currents known.

In the area of the Alaska Peninsula and Aleutian Islands, including the Pribilof Islands and the island of Kodiak, and in the northern portion of the Bering Sea in the vicinity of Kuskokwim Bay, and Norton and Kotzebue Sound, the tide range and tidal currents are generally lower. Diurnal tides in these areas range between 0.5 and 3.3 m (2.9-10.8 ft) at Nome and Port Moller, respectively. The predicted maximum tidal current speed at Port Moller is 0.97 m/sec (1.9 kn).

It should be noted that seafood processing operations that occur at a fixed position (i.e., shore-based and anchored floating processors) generally choose to operate in locations that are relatively protected so that fishing and supply vessels can easily dock and transfer catch or load finished products. The locations of seafood processing operations in Alaska can be generally represented by four physical oceanographic environments.

- Protected bays or harbors with reduced wave action, but possibly significant tidal currents.

- Nearshore open coastal areas which are affected by wave action depending on the water depth and wind- and tidally-driven currents.

- Rivers or estuary mouths with some wave action and a predominant tidal and freshwater influence.

- Open water which is affected primarily by wind-driven currents, although tidal currents may be important at some locations.

Because stationary operations are typically located in coastal environments with reduced currents and wave action, discharges from these facilities are most likely to result in the accumulation of solid waste on the bottom in the vicinity of the discharge.

3.1.2 Seafood Waste Particle Settling and Resuspension Current Speeds

Seafood waste particle settling velocities and the current speeds required to resuspend deposited waste particles are important factors that affect the fate, transport, and persistence of the seafood waste solids that are discharged. Estimates of these variables for seafood waste solids are summarized below.

3.1.2.1 Settling Velocities of Seafood Waste Particles. Ground seafood waste that is discharged are required to consist of solid particles that are no larger than 1.3 cm (0.5 in) in any dimension. Currently, no studies have been identified that have adequately characterized the particle size distribution of ground seafood waste or the characteristic settling velocities of these particles. However, one study of the open-water disposal of ground seafood waste conducted in Chiniak Bay, Kodiak Island, Alaska, provides a first-approximation of the settling velocities of seafood waste particles (Stevens and Haaga 1994). Unground particles (primarily gills, skin, fins, and viscera 5-25 cm in diameter) required approximately 0.5 hr to settle to the bottom at depths of 120 to 150 m (394-492 ft) (Stevens and Haaga 1994). Smaller particles (less than 1 cm diameter) required more than 1 hr to settle to the bottom. These ranges in settling times and water depths provide approximate bounds for the settling speeds of typical seafood waste particles of 0.03 to 0.08 m/sec (0.098-0.262 ft/sec).

An approximation of the settling velocities of seafood waste particles can also be predicted using the method described by Sleath (1984). This method calculates the settling velocity of a smooth, non-rotating spherical particle of a specific diameter and density in a motionless fluid. The density of a seafood waste particle can be approximated assuming a density of 1.0, 1.5, 0.9, and 3.0 for water, protein, fat/carbohydrate, and bone/chitin, respectively, and a percent water, protein, fat/carbohydrate, bone/chitin content of 75, 15, 7, and 3, respectively (see Table 2-10). These assumptions result in an estimated particle density of 1.13 g/m^3. The calculated settling velocities of spherical particles with diameters ranging from 0.1-1.3 cm (0.04-0.51 in) and a density of 1.13 g/m^3 are shown in Table 3-2.

These predicted settling velocities are generally much greater than those suggested by the observations of Stevens and Haaga (1994) described above. A spherical particle density that would result in settling velocities that were more consistent with the observations of Stevens and Haaga (1994) is 1.05 g/m^3 (see Table 3-2). The differences between the predicted and observed settling velocities may be due to 1) differences in particle sizes (the particle size distribution observed by Stevens and Haaga may have been biased to larger particles), 2) overestimation of actual settling velocities for a given particle density using the method described in Sleath (1984) due to non-spherical particle shapes and greater drag forces of the actual particles, or 3) overestimation of the actual particle densities. The method described by Sleath (1984) has been developed for idealized particles and has been applied most successfully to predicting the settling velocities of fine mineral particles with relatively small diameters. This method may not be as reliable for the prediction of the settling velocities of relatively large, irregularly shaped organic waste particles.

*3.1.2.2 **Resuspension Current Speeds***. The settling velocity of the solid waste particles (and the height of the discharge above the bottom) affects the initial areal extent of the deposit of solid waste on the bottom in the vicinity of the discharge. However, in regions which experience high currents it is important to consider the potential for the solid waste particles to be resuspended following deposition. If solid waste is resuspended and transported away from the vicinity of the discharge, the accumulation of solid waste would be less than that predicted based on the settling velocity and decay rate of the waste solids. The potential adverse impacts to benthic communities would also be reduced.

Resuspension and transport of deposited seafood waste solids is possible if the current speeds are sufficiently large. Periodically high current speeds can result due to wind, tide, or wave action along the coast. Along the coast of Alaska, the currents in many areas are dominated by semidiurnal tidal currents. These can be approximately represented as a sine wave with amplitude equal to the maximum current speed. Assuming that the maximum current speed exceeds the critical resuspension current speed required to lift waste particles off the bottom, then resuspension and transport of material is possible during a portion of a tidal cycle. The amount of material transported depends on the duration and frequency of occurrence of the critical current speed. The critical current speed depends on the size and density of the waste particles, and the cohesiveness of the waste accumulation on the bottom.

The critical resuspension current speed [i.e., the critical current speed 1.0 m (3.3 ft) above the seafloor (U_{100})] can be estimated for a particle of specified diameter and density in a non-cohesive sediment using Shield's diagram (Vanoni 1977) to compute the critical shear velocity u_* and the relation $u_* = (0.003)^{0.5} * U_{100}$ (Sternberg 1972). Critical resuspension current speeds calculated using this method are shown in Table 3-2 for the same particle sizes and diameters used to estimate settling velocities. These current speeds are necessarily first-approximations because the critical resuspension current velocities predicted using this method do not incorporate the effect of the cohesiveness of the waste solids accumulation which will necessarily resist resuspension and transport (Nowell et al. 1981). Diver observations of seafood waste piles have often noted a microbial mat over the surface of the pile which may increase the resistance to resuspension of decaying waste (e.g., U.S. EPA 1991). The actual critical resuspension current speeds are therefore likely to be higher than those shown in Table 3-2.

Although resuspension current speeds are likely to be higher near the bottom in shallow water than in deeper water, it should not be concluded that it would be more advantageous to locate seafood waste discharges in shallow waters. Shallow wastewater discharges will result in relatively lower initial dilution of the soluble portion of the waste due to the limited volume of dilution water available in shallow areas. Discharges in shallow nearshore waters also increases the potential for the surfacing of the waste plume and the accumulation of solids along the shoreline in the vicinity of the outfall.

3.1.3 Seafood Waste Decay and Loss Processes

Waste solid and liquid (i.e., particulate and dissolved) organic matter is decomposed by bacteria and eaten by scavenger organisms when released into the environment. The rate of decomposition or decay not only determines the persistence of the released organic matter, but the decay also results in the consumption of oxygen and the release of soluble compounds including nitrogen (e.g., ammonia), phosphorus (as soluble phosphorus), carbon dioxide, hydrogen sulfide, and methane.

Microorganisms mediate the chemical oxidation responsible for the degradation of organic matter. Microorganisms require an electron acceptor to accomplish this reaction, and different electron acceptors yield different amounts of usable energy. In the environment, the degradation of organic matter involves a series of reactions, each successive reaction yielding less energy per unit of carbon oxidized than the previous reaction. Simplified forms of these reactions are presented in Table 3-3. It is also important to note that the stoichiometry of organic matter, here formulated as $(CH_2O)_x(NH_3)_y(HPO_4)_z$, is much more complex than represented. The organic matter is actually composed of various complex chemicals that may be generally grouped as proteins (amino acids) and soluble material (which contain nitrogen, phosphorus, and sulfur), fats and carbohydrates, and proteinaceous mineral matter that comprises skeletal and connective tissue (e.g., chitin which also contains nitrogen) (see Section 2.6.1).

A more detailed organic matter composition can be approximated to better describe the amount of nitrogen, phosphorus, and sulfur that is liberated during the organic matter microbial decay process. The relative amount of these elements varies among the various types of organic matter. For example, Vollenweider (1985) described the theoretical stoichiometry of protein, lipid, and chitin with the following chemical formulas:

- Protein and soluble material: $C_{61}N_{16}H_{100}O_{24}SP$[1]

- Chitin and connective tissue: $C_{32}N_4H_{56}O_{20}$

- Fats and carbohydrates: $C_{15}H_{30}O$.

All of the sulfur and phosphorus and most of the nitrogen is contained in the protein and soluble fraction of the organic matter.

The rate of decay of organic matter depends on several factors including the composition of the material (i.e., refractory or labile) and decomposition pathways which depend on the chemical (e.g., oxic vs. anoxic) and physical (e.g., temperature and currents) environment. Values of organic matter decay rate constants reported in the literature are extremely variable (see Table 3-4), ranging over five orders of magnitude (1.6×10^{-6} to 1.4×10^{-1} day^{-1}).

Only one study of the decomposition of discharged seafood waste solids has been identified. In this study Tetra Tech (1986,1987) developed and calibrated a seafood waste pile decay model to predict the accumulation and decay of solid seafood waste disposed in Akutan Harbor, Alaska. The model assumed that: 1) all of the waste discharged accumulated at the point of discharge (i.e., no losses due to resuspension or slumping and transport) and 2) the decay of the pile was due only to microbial activity (i.e., scavenging by organism was not an important loss process). Decay rates were developed for the aerobic and anaerobic decay of fish and crab composed of protein, fats and carbohydrates, and bone or chitin. The first-order decay rate constants that provided a reasonable fit to the available data on the temporal variability of the waste pile volumes were 0.1, 0.01, and 0.001/day for aerobic decay and 0.01, 0.005, and 0.0005/day for anaerobic decay of protein, fats and carbohydrates, and bone/chitin, respectively (Tetra Tech 1986,1987).

The activity of scavenging organisms may also account for the reduction in the volume of accumulated waste in the vicinity of the discharge. However, no quantitative information regarding the consumption

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[1] The elements of the chemical formula are designated by the following symbols: C = carbon, N = nitrogen, H = hydrogen, O = oxygen, S = sulfur, and P = phosphorus.

(i.e., loss) rate of seafood waste by organisms has been identified. However, marine organisms such as fish and invertebrates have been observed to feed on recently discharged solid waste particles (Hill, B., 8 June 1994, personal communication; Stevens and Haaga 1994). No quantitative studies regarding the importance of this activity have been identified.

The microbial decomposition process results in the liberation of a number of soluble compounds depending on the supply of electron acceptors (e.g., oxygen, nitrate, and sulfate) and the oxidation-reduction state of the environment and the amount liberated depends at least partly on the rate of decay of the organic matter (Froelich et al. 1979; Aller 1982). The microbially mediated reactions typically proceed in a predictable sequence based on the amount of energy released from the reaction beginning with the aerobic decomposition of in the presence of oxygen, nitrate reduction of organic matter using nitrate as an electron acceptor and iron and manganese reduction in the near absence of oxygen, and sulfate reduction, methane production, and fermentation in the absence of oxygen (see Table 3-3). All of the microbial decay processes result in the liberation of soluble phosphate. Additional biological and chemical reactions can result in the assimilation of the released phosphate or the binding of phosphate to mineral particles. However, several studies have found that the amount of phosphorus actually released is typically greater than that predicted using stochiometric models due to the release of mineral-derived phosphates bound to sediments under the near anaerobic conditions typical of organic rich sediments (e.g., Almgren et al. 1975; Froelich et al. 1979). Nitrate and ammonia nitrogen compounds are also released from decaying organic matter, but additional microbial reactions such as assimilation and the transformation of ammonia to nitrate (i.e., nitrification), and nitrate to nitrogen (i.e., denitrification) serve to reduce the amount of ammonia and nitrate release to the overlying water column. The underestimation of the amount of nitrogen compounds released during organic matter decay using stochiometric models has been attributed to the loss of these compounds via nitrification-denitrification (e.g., Almgren et al. 1975). Hydrogen sulfide is also produced from the reduction of sulfate during anaerobic decay of organic matter in the presence of sulfate. However, additional chemical reactions complicate the prediction of the amount of sulfide released from decaying organic matter using simple stochiometric models. These reactions include the rapid oxidation of sulfide (Almgren and Hagström 1974) and the binding of sulfide with mineral particles.

3.2 DEVELOPMENT OF A NUMERICAL MODEL TO PREDICT DEPOSITION OF SEAFOOD WASTE

Due to the diversity of Alaskan seafood processing operations and the variety of physical oceanographic conditions, a computer model of seafood processing waste discharges would provide a very useful tool to evaluate the transport, fate, and persistence of discharged seafood waste. The ideal computer model would simulate all of the relevant physical, chemical, and biological processes and provide predictions for all potential adverse impacts on marine and coastal communities including effects on fish, marine birds, and humans. However, due to limitations in the understanding of physical and chemical processes, interactions between chemical and physical processes and biological communities, and limitations in computing power, computer models are typically mathematical simplifications of the most relevant processes and interactions (Thomann and Mueller 1987, p. *x*). The following sections describe the selection and development of a computer model with the capabilities to predict the long-term accumulation of solid waste on the bottom in the vicinity of seafood processors discharging from a fixed location.

The new NPDES general permit classifies Alaskan seafood processing operations into three categories.

- *Offshore floating seafood processors*—operating and discharging more than one (1) nautical mile (1.9 km) from shore at MLLW.
- *Nearshore floating seafood processors*—operating and discharging from one (1) to one-half (0.5) nautical mile (1.9-0.9 km) from shore at MLLW.
- *Shore-based seafood processors*—operating and discharging less than one-half (0.5) nautical mile (0.9 km) from shore at MLLW.

It is predicted that significant accumulations of seafood solid waste will only occur in the vicinity of *nearshore floating* and *shore-based* seafood processing operations that discharge at a single fixed location. *Offshore* floating processors are not expected to remain in a single location, and therefore the solid wastes discharged by these facilities will be dispersed and will not result in a persistent accumulation of solid waste on the bottom. A study of the disposal of seafood solid wastes in the offshore waters of Chiniak Bay, Alaska, indicated the rapid disappearance of bottom deposits of seafood waste (Stevens and Haaga

1994). Therefore, the modeling effort focused on the prediction of solid waste accumulations in the vicinity of *nearshore* and *shore-based* facilities that discharge from a single fixed location.

3.2.1 Model Selection

Two EPA-supported computer models were initially identified that could effectively model the deposition, decay, accumulation, and areal extent of seafood solid waste. The two EPA models identified were the Simplified Deposition Calculation (DECAL) (U.S. EPA 1987) and the Water Quality Analysis Program Version 5.10 (WASP5) (Ambrose et al. 1988). Both models were considered suitable for modeling the deposition, decay, and accumulation of seafood solid waste. However, WASP5 is also capable of modeling water column dissolved oxygen and nutrient-phytoplankton interactions. These additional capabilities of WASP5 as well as the potential to incorporate the influence of relatively complex shorelines and tidally-varying current speeds and directions resulted in the selection of the WASP5 model for use in predicting the areal extent of seafood waste solids accumulation. However, the additional complexity of the WASP5 model results in some sacrifice in ease of use and increases the amount of computing time required to run the model. The original WASP5 computer code also required some modifications to accommodate the prediction of organic solids decay and accumulation.

3.2.2 Description of the Modified WASP5 Model

The existing WASP5 and EUTRO5 (a sub-model component of WASP5) models (version 5.10) were modified by adding three state variables to represent three size classes of seafood waste solids particles. The proportion of solids in each of the three size classes and their settling velocities can be specified in the model. Seafood waste solids are modeled on a dry weight basis with decomposition accounted for in the oxygen balance through a 50 percent carbon:dry weight ratio and a stoichiometric factor of 2.67 g O_2/g C. Additional secondary output variables were added to the EUTRO5 sub-model to track the dry weight deposition flux of each size class of seafood waste as it passed from the water column to the bottom sediments. Also, additional kinetic constants were added to the EUTRO5 sub-model to account for the carbon:dry weight ratio and the first-order decomposition rates in the water column and sediment layers.

The current model uses a simple scheme of a steady along-shore net-drift current speed. This is the long-term net transport rate away from the point of discharge. Longitudinal, lateral, and vertical dispersion coefficients are used to approximate the spreading of the waste due to tidal actions. As currently modified, the model does not account for resuspension and transport of deposited waste solids. The potential for resuspension and transport can be assessed using estimates of the resuspension current speeds necessary to transport deposited solid wastes, and site specific information regarding average maximum current speeds, peak current speeds, and their duration.

The modeling grid system consists of a variably-spaced Cartesian grid system with two water column layers and one benthic layer. In the vicinity of the discharge there are 25 small segments each having a dimension of 18x18 m (59x59 ft) which provides a 0.81 ha (2.0 ac) coverage of fine resolution computational cells (see Figure 3-2). As one moves away from the discharge, the segment sizes become progressively larger. The entire grid system consists of 300 water column segments and 150 benthic segments.

Because WASP5 does not explicitly model the initial dynamics of the buoyant wastewater plume, the waste discharge point source is located between the upper and lower water layers that are simulated in the model. The effect of density stratification on mixing and dilution of the wastewater plume is not considered in the model.

The current version of the model provides predictions of the areal extent and the depth of the seafood waste deposit depending primarily on the horizontal dispersion coefficients, mass emission rate of seafood waste solids (in dry weight), the settling velocities and proportions of solids in each of the three particle classes, the first-order decay rate of waste solids, and the net-drift current speed.

3.2.3 Selection of Modeling Case Scenarios

Twelve modeling case scenarios were developed for application of the WASP5 model to assess the potential for accumulation of seafood solid waste under a variety of conditions (Table 3-5). These scenarios included six simulations for discharges from shore-based facilities with discharges located 2.0 m (6.6 ft) above the bottom in 15.2 m (50 ft) of water. Combinations of low and medium net-drift current speeds [5 and 15 cm/sec (0.10 and 0.29 kn)] and three bottom slopes (0.0, 12.5, and 25 percent) resulted in the six case scenarios modeled for shore-based discharges. These scenarios were selected to evaluate the effect of varying slope and current velocities on the model-predicted accumulation of seafood waste solids from shore-based facilities.

Six case scenarios were also selected to evaluate the effect of varying current speed and water depth on the model-predicted accumulation of seafood waste solids due to surface discharges from stationary floating processors. These simulations included a discharge 2.0 m (6.6 ft) below the water surface in water depths of 15.2, 30.5, and 45.7 m (50, 100, and 150 ft) and a low and medium current speed. The bottom slope in all of these cases was 0.0 percent (i.e., a flat bottom).

For each modeling case scenario, the model was run for varying steady mass emission rates to determine the waste solids mass emission rate that would result in the bottom accumulation 1.0-cm (0.39-in) deep or more over a 0.40 ha (1.0 ac) area at steady-state (i.e., decay losses balanced by waste inputs). Although the WASP5 model has the capability to model time-varying solids mass emission rates, a steady (e.g., annual average) mass emission rate was used to simplify the estimation of the steady-state accumulation of waste solids.

3.2.4 Selection of Model Input Variables

Based on the information provided in Section 2.0 on the characteristics and quantity of Alaskan seafood waste and additional information provided above in Section 3.1, the values for several model input variables were selected for use in the modeling case scenarios. These values were considered to be reasonable estimates for a typical seafood processing waste discharge and receiving water characteristics. Because of the limited information for a number of the model variables (e.g., the first-order organic matter decay rate constant), the selection of input values for these variables was necessarily based somewhat on professional judgement. Due to the relative uncertainty of the values selected, the results of the modeling case scenarios should be considered a first-approximation. However, the modeling case scenarios do provide an indication of the relative sensitivity of the model to the factors that are varied in each case. Sensitivity of the model to particular variables will suggest which variables should be the focus of future laboratory or field investigations.

Table 3-6 shows the variables that were selected for use in the modeling case scenarios. The rationale for the selection of the values for the proportion of solids in the three size classes and their settling velocities and the first-order waste solids decay rate constant is described below.

3.2.4.1 Solids Distribution and Settling Velocities. The settling velocities of the three particle classes were selected from Table 3-2 and were chosen to approximate the range of settling velocities observed by Stevens and Haaga (1994). For lack of better information the distribution of solids in each of the three particle classes was selected as follows. Sixty percent of the waste solids was assumed to be composed of particles with settling velocities of 0.085 m/sec (0.28 ft/sec). Conceptually these are the waste particles with a diameter of 1.3 cm (0.5 in). Twenty percent of the waste solids were assumed to be composed of particles with settling velocities of 0.045 m/sec (0.15 ft/sec). Conceptually these are particles with a diameter of 0.635 cm (0.25 in). Twenty percent of the waste solids were assumed to be composed of particles with settling velocities of 0.022 m/sec (0.072 ft/sec). Conceptually these are particles with a diameter of 0.318 cm (0.125 in).

3.2.4.2 ***Waste Solids Decay Rate Constant.*** Because of the wide range of possible organic matter decay rates, and because of the uncertainty regarding the significance of scavenging of the waste by organisms, the model waste solids decay rate constant was estimated by holding all model variables constant (the low current speed case was used) and comparing the model results to an actual Alaskan seafood waste discharge with a known annual discharge rate and a reasonably well surveyed waste accumulation in the vicinity of the discharge. It was assumed (although no data were available to verify the assumption) that the actual waste accumulation was not affected by resuspension and transport of the waste that had been deposited. The areal extent of the waste accumulation predicted by the model was compared to the observed areal extent of the actual waste accumulation. The model decay rate constant was adjusted until a reasonable agreement was obtained between the bottom coverage predicted by the model and the observed waste coverage.

This comparison process resulted in the estimation of a first-order waste decay rate constant of 0.02 day^{-1} which is within the range of values presented in Table 3-4.

If field data had been available for the net-drift current speed, waste solids particle distribution, and particle settling velocities for the actual discharge studied, the decay rate could have been estimated more precisely. Nonetheless, the method used to estimate the decay rate likely provided a reasonable estimate of a decay rate constant that has been shown to vary over five orders of magnitude depending on the environment and type of organic matter (see Table 3-4).

3.3 MODELING CASE SCENARIO RESULTS

The WASP5 seafood waste accumulation model was run iteratively to predict the steady-state solid waste discharge rate that would produce a bottom accumulation of seafood waste with a depth of 1 cm or greater over an area of 0.40 ha (1.0 ac) (Table 3-7). These results provide a first-approximation of the annual seafood solid waste discharge rate that would result in a bottom accumulation of seafood waste equal or exceeding the proposed zone-of-deposit of 0.40 ha (1.0 ac). This iterative process was conducted for each of the twelve case scenarios. The model predictions are based on the assumption that resuspension and transport is negligible. Resuspension and transport of deposited solids may occur at individual facilities if bottom current speeds exceed the critical current speed required to resuspend bottom waste accumulations (see Section 3.1.2.2). Therefore, the model predictions may be considered conservative estimates of the potential for waste accumulation under the conditions described in the model for the twelve case scenarios. The results for the near-bottom shore-based and near-surface floating discharges are summarized and discussed below.

Two estimates of the areal extent of the waste pile have been provided in Table 3-7. The first areal coverage estimate is based on interpolation of the WASP5 model-estimated waste deposit depths in each modeling cell using the computer program SURFER™. This program creates contour plots of the depth of the waste pile based on the model-estimated waste deposit depths in each WASP5 modeling cell and calculates the area covered by waste deposits 1 cm deep or greater (Figure 3-3). The second estimate of the areal extent of the waste pile is based on summing the areas of the WASP5 modeling cells that contain accumulations of seafood waste solids 1 cm deep or greater. For example, if the waste accumulation was greater than 1 cm in all of the smallest WASP5 modeling cells near the discharge point [i.e., 9, each with an area of 0.03 ha (0.08 ac)] in the vicinity of the discharge, then the estimated areal coverage of seafood waste solids greater than 1 cm deep would be 0.27 ha (0.72 ac). For the near-bottom shore-based and near-surface modeling case scenarios the two estimates are similar, generally within 20 percent.

3.3.1 Near-Bottom Shore-Based Discharges

The first-approximation of the annual near-bottom shore-based seafood waste solids discharge that would result in a waste accumulation greater than 0.40 ha (1.0 ac) in waters with a net-drift current speed of 5.0 cm/sec (0.16 ft/sec), a depth of 15.2 m (50 ft), and a flat bottom is 16 million pounds (wet weight) of waste solids. The maximum accumulated solids depth of this pile is predicted to be 230 cm (7.5 ft). The first-approximation of the amount of seafood waste solids discharge that would result in the accumulation of greater than 0.40 ha (1.0 ac) of seafood waste on the bottom in waters with a net-drift current speed of 15.0 cm/sec (0.49 ft/sec), a depth of 15.2 m (50 ft), and a flat bottom is 12 million pounds of waste solids. The maximum accumulated solids depth of this pile is predicted to be 133 cm (4.4 ft). The first-approximation of the amount of seafood waste solids discharge that would result in the accumulation of greater than 0.40 ha (1.0 ac) of seafood waste on the bottom in waters with a net-drift current speed of 5.0 cm/sec (0.16 ft/sec), a depth of 15.2 m (50 ft), and a sloping bottom (12.5% and 25%) is 20 million pounds of waste solids (see Cases 3 and 5, Table 3-7). The maximum accumulated solids depth of these piles are predicted to be 230 and 288 cm (7.5 and 9.4 ft, respectively). The first-approximation of the amount of seafood waste solids discharge that would result in the accumulation of greater than 0.40 ha (1.0 ac) of seafood waste on the bottom in waters with a net-drift current speed of 15.0 cm/sec (0.49 ft/sec), a depth of 15.2 m (50 ft), and a sloping bottom (12.5% and 25%) is between 12 and 16 million pounds of waste solids (see Cases 4 and 6, Table 3-7). The maximum accumulated solids depth of these piles are predicted to be 179 cm (5.9 ft).

The model predicts that less waste discharge is required to create a 0.40 ha (1.0 ac) pile 1 cm deep or greater when the current speed is higher because the higher current speed serves to spread the waste over a larger area. The model predicts that the waste accumulation will be relatively deep [i.e., greater than 1 m (3.3 ft)] because the simulated discharge is 2 m (6.6 ft) above the sea floor and the waste particles settle rapidly to the bottom in the vicinity of the discharge. The model also predicts that on sloping bottoms, more seafood waste can be discharged than on a flat bottom before a pile greater that 0.40 ha (1.0 ac) is created.

The model-predicted estimates of the near-bottom shore-based waste discharges that would result in a 0.40 ha (1.0 ac) waste pile are consistent with the limited data on actual waste pile accumulations in the vicinity of several shore-based seafood processing facilities. The maximum areal extent of waste pile deposits summarized in Section 2.6, 0.3 ha (0.7 ac), was associated with a 1993 annual solids discharge rate of approximately 11.1 million pounds of seafood waste.

3.3.2 Near-Surface Floating Discharges in Open Ocean

The first-approximation of the annual near-surface open water seafood waste solids discharge that would result in a waste accumulation greater than 0.40 ha (1.0 ac) in waters with a net-drift current speed of 5.0 cm/sec (0.16 ft/sec), a depth of 15.2 m (50 ft), and a flat bottom is 8 million pounds (wet weight) of waste solids. The maximum accumulated solids depth of this pile is predicted to be 63.4 cm (2.1 ft). The first-approximation of the amount of seafood waste solids discharge that would result in the accumulation of greater than 0.40 ha (1.0 ac) of seafood waste on the bottom in waters with a net-drift current speed of 15.0 cm/sec (0.49 ft/sec), a depth of 15.2 m (50 ft), and a flat bottom is 4 million pounds of waste solids. The maximum accumulated solids depth of this pile is predicted to be 19.2 cm (2.1 ft). The first-approximation of the annual near-surface open water seafood waste solids discharge that would result in a waste accumulation greater than 0.40 ha (1.0 ac) in waters with a net-drift current speed of 5.0 or 15.0 cm/sec (0.16 or 0.49 ft/sec), depths of 30.5 or 45.7 m (100 or 150 ft), and a flat bottom is approximately 4 million pounds (wet weight) or less of waste solids. The maximum accumulated solids depth of these piles are predicted to be 8-24 cm (0.3-0.8 ft).

The model predicts that discharges to near-surface waters will result in areal coverage of 0.40 ha (1.0 ac) of the bottom with significantly less seafood waste discharged than the near-bottom discharge model cases. These results can be explained by the fact that seafood waste discharges to the near-surface waters are exposed to the currents during settling for a longer time than the near-bottom discharges, and consequently, are dispersed over a larger area. As can be seen from the predictions of the maximum waste accumulation depths, the volume of material that accounts for the 0.40 ha (1.0 ac) coverage is much less than for the near-bottom discharges (see Table 3-7).

3.3.3 Modeling Case Scenarios Summary

The modeling results suggest the complexity of the regulation of seafood waste discharges. Tradeoffs are evident between the desire to minimize the appearance of wastewater and waste solids at the water surface, the transport of the waste onshore, and the accumulation of waste solids on the bottom, while also trying to maximize the dispersion and dilution of the waste. For shore-based facilities, the seafood waste accumulation model predicts that relatively deep [greater than 1 m (3.3 ft)] waste deposits will occur when the end of the discharge pipe is 2 m (6.6 ft) above the bottom. Increasing the net-drift current speed to 15.0 cm/sec (0.49 ft/sec) spreads the waste over a larger area, increasing the areal coverage of the waste pile. At these current speeds the areal extent of the bottom waste accumulation appears to be controlled primarily by the current speed and not by the amount of the waste discharged. At higher current speeds greater areal coverage of the waste is predicted. On the other hand, the WASP5 seafood waste accumulation model of near-surface discharges from floating facilities predicts relatively shallow deposits [approximately 8-24 cm (0.3-0.8 ft) deep] for the low and medium (5 and 15 cm/sec, respectively) current speeds modeled. Under these conditions the areal extent of the waste pile greater than 1 cm (0.4 in) deep is controlled primarily by the discharge rate. Greater areal coverage of the waste from near-surface discharges is predicted for lower discharge rates than from near-bottom discharges (see Table 3-7).

The model predictions discussed above are considered conservative estimates of bottom waste accumulation because the WASP5 model does not consider the resuspension and transport of deposited wastes. Therefore, actual bottom accumulations at facilities where current speeds sufficient to resuspend and transport significant amounts of deposited wastes will tend to be much less than those predicted by the model. A first-approximation of the likelihood that resuspension and transport of deposited seafood wastes may occur can be made by estimating or measuring current speeds in the vicinity of individual facilities and comparing them to the estimated resuspension current speeds in Table 3-2.

3.4 SUMMARY

A conceptual model of the fate, transport, and persistence of seafood processing waste was developed that also identified the potential adverse biological effects caused by this discharge. A number of biological, chemical, and physical factors control the fate of the discharged wastes. Biological factors include microbial decay and scavenging of the waste by organisms. Chemical factors include the chemical composition of the waste, particularly the content of protein and soluble organic compounds, fats and carbohydrates, and skeletal and connective tissue. Each of these components has a characteristic chemical composition and decay rate. Physical factors that control the fate, transport, and persistence of the waste include density stratification, storm-, tidal-, and wind-induced currents, and water temperature. Current speed direction and duration strongly influences the transport and dispersion of the waste and critical current speeds can resuspend and transport waste solids deposited on the bottom. Although simple stoichiometric models of organic matter decay have been used by some researchers to predict the release of soluble compounds to the overlying water due to the microbial decay of organic matter, there are a complex of coupled reactions that complicate the reliability of these simple model predictions. These models typically under- predict the amount of soluble phosphorus released, due to the additional release of mineral-bound phosphorus, and these models over-predict the release of ammonia nitrogen and hydrogen sulfide because of additional microbial processes and chemical reactions that reduce the concentrations of these compounds in the overlying water.

A mathematical model was developed to simulate the discharge and accumulation of solid wastes from discharges near the bottom from shore-based facilities, and discharges near the surface from floating processing facilities in open water. Two current speeds (5 and 15 cm/sec) were simulated. For the simulations of shore-based facilities the bottom slope was varied resulting in six case scenarios, and for the floating facilities the water depth was varied which also resulted in six case scenarios. The model was used to provide a first-approximation of the amount of waste solids discharge that would result in an approximately 0.40 ha (1.0 ac) bottom deposit of seafood waste. The modeling results indicated that a steady annual discharge from a shore-based facility of approximately 12-20 million pounds (wet weight) of solid waste would be required to produce a 0.40 ha (1.0 ac) deposit in the absence of significant resuspension and transport of the deposited waste. For a near-surface discharge in 15.2-m (50 ft) water depth a steady annual discharge of approximately 8 million pounds would be required to produce a 0.40 ha (1.0 ac) deposit. In water depths greater than 15.2 m (50 ft), seafood waste discharges of 4 million pounds or less are predicted to create waste deposits of 0.40 ha (1.0 ac).